

Description

SYSTEM AND METHOD FOR FACILITATING FLUID THREE-DIMENSIONAL MOVEMENT OF AN OBJECT VIA DIRECTIONAL FORCE

BACKGROUND OF INVENTION

[0001] This application is a continuation in part of United States Patent Application Ser. No. 10/604,525, filed on July 28, 2003 entitled "System and Method for Moving Objects within Three-Dimensional Space" which is hereby incorporated herein by reference. This application is a continuation in part of United States Patent Application Ser. No. 10/708,158, filed on February 12, 2004 entitled "Cabling System and Method for Facilitating Fluid Three-Dimensional Movement of a Suspended Camera" which is hereby incorporated herein by reference.

[0002] FIELD OF THE INVENTION

[0003] Embodiments of the invention described herein pertain to

the field of aerial cable rail systems. More particularly, these embodiments enable the movement of objects within three-dimensional space.

[0004] **DESCRIPTION OF THE RELATED ART**

- [0005] An aerial cable rail system is a system based on an elevated cable or rope, along which objects are transported. Existing cable rail systems rely on large fixed structures and/or complex control systems in order to facilitate the movement of objects. Many of these systems are impractical or difficult to use in that such systems typically fail to satisfactorily achieve the full spectrum of platform stability, ease of control, a compact footprint, ease of transport, speed, load bearing, extensibility, maintainability and platform stability.
- [0006] Objects have been supported and moved through three-dimensional space via ropes and cables for various purposes in the past. In U.S. Patent 494,389 to Sherman granted in 1893, a device is described allowing for movement of a hoist through three dimensional space via a complex arrangement of cables and pulleys. A logging system is described in U.S. Patent 1,782,043 to Lawson granted in 1926 employs large amounts of cable and extensive reeving in order to suspend and move logs over

large distances. A similar rope crane is described in U.S. Patent 3,065,861 to Cruciani granted in 1960. These systems generally employ one or more highlines which are tightly stretched and from which an object is suspended. Other patents such as U.S. Patent 3,043,444 to Melton granted in 1962 and French patent 2,318,664 to Kennedy granted in 1977 took a different approach to suspending and moving objects through three dimensional space by using one cable per support pulley per winch. The '444 and '664 patents minimize the amount of cable in the system but do not allow for simple control of the cables in the system since the speeds and lengths of each cable must change non-uniformly depending upon the path of motion of the supported object.

- [0007] The cable movement systems previously mentioned were generally used to haul equipment or material. Simple cable support systems have also been used to support cameras in three-dimensional space on ropes with varying degrees of success. In U.S. Patent 367,610 to Fairman granted in 1887, a balloon moved with two guy lines is described that allows a camera to take pictures from locations high above the ground. In U.S. Patent 578,980 to Eddy granted in 1897, a group of cameras is hoisted on a

kite string attached to a reel in order to capture panoramic photographs. In U.S. Patent 894,348 to Seele granted in 1908, a camera is dropped from a balloon in a sphere in order to eliminate the undesirable pendulum effects and motion effects of wind from the resulting photograph that is exposed when a shutter string is fully extended. The '348 patent may possibly be the first patent that attempts to isolate an airborne camera from the jarring effects of the vehicle carrying the camera. In U.S. Patent 1,002,897 to Brown granted in 1911, a camera is directly attached to a kite string with a timer in the form of a propeller that takes a picture after a certain period of time. In U.S. Patent 1,301,967 to Parks granted in 1919, a kite string based camera is described that travels along the kite string to a preset point takes a photograph and automatically descends back down the kite string so that the kite does not have to be lowered between photos.

- [0008] During the 1920's work was begun on stabilizing cameras carried in vehicles since the movement of the vehicles was limiting the quality of the photographs obtained. In U.S. Patent 1,634,950 to Lucian granted in 1927, a gyro-stabilized camera mount is described that actively stabilizes a camera in the pitch and roll axes in order to keep a

camera actively isolated from the undesired angular motion of the aerial, land or marine vehicle carrying the camera through three-dimensional space. Many other gyro-stabilizer patents were awarded after Lucian '950 and teach active stabilization for equipment when that equipment is supported by a moving vehicle.

- [0009] In U.S. Patent 4,710,819, a camera suspension system is described that utilizes a minimum of at least three cables wherein each cable has two ends with one end of each cable fixedly attached to an equipment support member and the other end of each cable fixedly attached to a winch. In between the fixedly attached endpoints lies a pulley that is used as a support for the cable to provide a vertical offset between the ground and the equipment support member. Movement is achieved by reeling the cables in and out to position the camera with motion between two points generally requiring all cables to move simultaneously at different rates.
- [0010] In U.S. Patent 4,625,938, a camera support system is disclosed in which a camera payload can be moved within three-dimensional space in a way that allows for active stabilization of velocity of the panning (vertical axis) of the equipment support member.

- [0011] In U.S. Patent 5,440,476, a cable support system is described for moving objects by extending and retracting independent ropes that correspond one-to-one with the number of winches and support pulleys supporting a central object. Even simple one axis movement requires that all ropes in the system change length in a coordinated fashion to prevent slack in the other ropes supporting the object. The '476 device cannot be operated in its best mode without a computerized control system as is true for the '938 and '819 devices previously mentioned.
- [0012] In U.S. Patent 6,566,834, an invention is disclosed in which a payload can be moved and angularly positioned within three-dimensional space. The invention requires a computer control system in order to calculate the change in lengths of the supports ropes in order to move the payload between two points. The invention appears to require power at the platform and locates the winches for the system on the platform, further reducing the payload capacity of the platform. Furthermore, the invention does not provide simple X, Y and Z independence for control purposes and it appears that complex sensing devices must be deployed in order to keep the cables tensioned properly.

[0013] In U.S. Patent 5,585,707, an invention is disclosed in which a robot or person can be readily moved within three-dimensional space. The payload is limited and the support structure is small scale. If the structure were to be scaled up, obstacles such as goal posts or light poles would inhibit the motion of the payload through a path between two points defined within the cube, since there are numerous wires required to practice the invention. Also, the invention would not appear to allow the Z-axis to vary beneath the cube, and the size of the cube support structure to service a large volume of space would be extremely expensive to build on the scale required. Again, complex control is required to keep the tension in all of the ropes at the correct level during movement of the supported equipment.

[0014] In U.S. Patent 5,568,189, an invention is disclosed for moving cameras in three-dimensional space. The problems with the '189 invention become apparent when attempting to enlarge the scale of the system. Figure 4 clearly shows how the two parallel highline cables sag inward, when the payload is in the middle of the X, Y space. Since the invention does not use strong rails to support the Y-axis rope, the weight bearing of the invention is de-

pendent upon the strength of the building or structure in which it is mounted and the springs in its weight bearing X-axis connectors. The motors for the various axes are mounted up in the rigging, which would require multiple extremely long power cables to traverse the volume of space along with the payload if the invention were modified for outdoor use. The power cables would total over 3 times the length of the longest axis to drive the far X-axis motor, the Y-axis motor and the Z-axis motor. Mounting heavy motors high in the rigging presents a major safety issue given that suspension lines can break. The size of the motors limits the payload that can be carried, and further limits the speed at which the payload can be carried. The invention is also fixed in size, not allowing for modular addition of X travel, or increasing the Y or Z-axis travel without mounting the structure in a bigger studio or building a bigger hanger. The system requires four ropes to move an object in three dimensions.

SUMMARY OF INVENTION

- [0015] Embodiments of the invention are ideally suited for moving objects through three-dimensional space using one or more lines. For instance, various embodiments of the invention provide mechanisms for positioning an object

such as a human, mining implement, logging implement, manufactured object or any other useful object such as a camera. Thus it is possible to use embodiments of the invention to shoot footage for film and television productions as well as, sporting events, or any other activity that benefits from fluid movement of a camera or other object to any position within a defined volume of space.

- [0016] To accomplish such positioning, embodiments of the invention are configured to move an object throughout three-dimensional space by relocating one or more lines that are feed through a plurality of sides of the object. These line(s) (e.g., a cable, rope, string, cord, wire, or any other flexible connective material) which support the object within a volume of space are arranged in way that allows the object to be rapidly moved to and from any location within the defined volume of space. For instance, the system may be arranged to perform three-dimensional movement using one line configured as an endless loop, one line configured as a half loop, two lines configured as endless loops or two lines configured as half loops.
- [0017] The exact arrangement of the line(s) depends upon which embodiment of the invention is implemented. However, in each instance a set of one or more lines suspend an ob-

ject by passing through a set of line support elements (e.g., one or more pulleys, sheaves, or any other support assembly configured to redirect line) and around a motorized push-pull wheel. The line support elements can comprise free wheeling elements or may be controlled elements, for example providing emergency brake components for automatically halting line travel in the event of a line break, or components to monitor or control vibrations. The motorized push-pull wheel is configured to relocate line to move the object and maintain suspension of the object in a given position. The line is moved via the push-pull wheel in way that enables movement of the object through the transferal of line between a plurality of sides of the object. The line is reeved in such a manner as to provide three junctions (for example in one embodiment two push-pull wheels and one winch) where the line can be subjected to force thereby moving an object in three dimensions. Movement in each of the three dimensions are substantially independent, with the X line allowing X-axis motion of the supported object and the Y line allowing Y-axis motion of the platform. In one embodiment of the invention X line and Y line may be joined to form sides of the same contiguous line. The X and Y axes

are not required to orthogonally intersect. Displacing equal lengths of the X and Y line via a junction (for example a winch, push-pull wheel, hydraulic device, screw device or other mechanism for displacing or relocating line) allows the Z-axis of the platform to be traversed. The Z axis is not required to project orthogonally from the plane created by the intersection X and Y axes and all support areas are not required to lie in the same plane.

- [0018] The system can be scaled to any size by employing longer lines and moving the supports. The supports themselves may be dynamically repositioned as well. Embodiments may be configured in scalene triangle or convex or concave quadrilateral arrangements where no two sides are required to have the same length nor equal distances or heights between any two supports. This holds for single line or two line embodiments of the invention or any variation of these embodiments. For simplicity of description of three-dimensional movement, the separate axes that a supported object may be moved are termed the X-axis, Y-axis and Z-axis wherein each of these axes are not required to project orthogonally from a plane formed by the other two axes.

- [0019] In an embodiment of the invention configured for exam-

ple in a rectangular configuration with four regions having any appropriate number of line support elements, the supported object is moved along the X-axis independently of movement along the Y-axis and therefore requires no complex control system. In this example, the Z-axis movement follows an ellipsoidal path (four foci ellipsoidal where the foci are the supports) that can be as flat or circular as desired depending on the shape of the area of coverage desired. In the case of an area of coverage over a physical potential well, for example a stadium or open pit mine that is deeper in the middle than on the sides, the X-axis and Y-axis motion can be configured with more or less line in the system to create a flatter or rounder elliptical shape in order to avoid the surface below since the Z-axis automatically traverses vertically when the object moves towards the sides of the area of coverage of the invention. The ellipsoidal path can be as flat or circular as desired depending upon the amount of line deployed in the system and the relative height of the supports. Displacing equal lengths of line into a plurality of sides of the supported object allows the Z-axis of the platform to be traversed which results in trivial control of the object. This technique of relocating line without the

need for a control system in order to move an object in three dimensions provides many advantages over the prior art that requires complex control software and active stabilization.

- [0020] Embodiments of the invention can also use a three support triangular configuration where no two sides are required to be the same length. For any topology that embodiments of the invention are configured, there is no ratcheting movement at the object since the same line supports an object on a plurality of sides with the object freely moving to the point of minimal potential energy based on the amount of line transferred from one side to another side of the supported object. In addition, the lengths of the line do not require adjustment in way that requires complex calculations and computer control since the junctions effecting movement of each axis are independently operated.
- [0021] In an embodiment of the invention line may be relocated from one area comprising X, Y and Z motors, and therefore distantly located motors and electrical cables are not required although they may be utilized if desired. Other advantages of embodiments of the invention utilizing collocated motors and junctions for relocating line include

allowing motors to be large, power cables to be short and located near a large generator and maintenance to be performed in one location. The line support elements (e.g., pulleys, sheaves, or any other mechanism that can redirect line) employed in the system may contain high speed bearings and may be configured to capture the line in order to prevent derailing thereby providing an added degree of safety to the system. The push-pull wheels may optionally comprise grooves that grip the line in order to prevent slippage. Any mechanism for driving or displacing line may be substituted for the push-pull wheels. Embodiments of the invention can utilize a push-pull wheel, reel or any mechanism for effecting movement of line to multiply Z-axis travel. The location of the various components in the system may be altered including modifications to the reeving while keeping with the spirit of the invention.

- [0022] The supported object may comprise many types of useful devices, and the object may then be further attached to a platform that may comprise passive or active stabilization. For instance, the terms object may refer, but is not limited to, a camera, mechanical claw, hoist or loader, mining scoop or any other equipment where three-dimensional movement may be desired. It is also possible to use em-

bodiments of the invention to effectuate three-dimensional movement of one or more persons. The word platform as used herein refers to any vehicle to which an object may be coupled for the purposes of movement through three dimensional space in any environment subject to a force, for example the force of gravity. For example, the platform itself could be supported and moved through the air or water with supports in the air or water so long as the platform is forced away from the supports. In one or more embodiments of the invention there may be more than one force at work on the platform, for example buoyancy and gravity. The platform may comprise an element that allows for the application of a directional force. The element could be a balloon, a sail, a counterweight, a buoyant counterweight, a ferromagnetic material, or any other element that would allow the platform or object being moved to become the subject of the directional force. The net force may provide a basis to move the platform in any direction, for example but not limited to the positive or negative direction with respect to the Z-axis, e.g., the force provided by wind. The Z-axis is not necessarily orthogonal to the face of the earth. The force could be magnetic or inertial for space based embodi-

ments, or gravity for example, or the result of activation of a propeller, a thruster, positive buoyancy either under water or in the air via an element less dense than water or air respectively, such as a balloon, or any other means by which the platform is forced away from the associated supports. The supports in some embodiments may at ground or seabed level and have positive, negative or zero height. The supported object may utilize an electrical or fiber optic cable festooned to a support along at least one line or may travel to a non support area and may be used for the transmission of video images or other data from the supported object to the ground or data may be transmitted from the platform via wireless technologies. Alternatively the platform may send and receive video or image data via a wireless connection such as a microwave or any other suitable transport protocol.

- [0023] The platform may comprise a structure which has a center of gravity well below the region where the lines pass through or couple with the platform. Movement of the platform is so stable that passive stabilization may be utilized in bottom heavy embodiments. Alternatively the lines may couple with the platform at approximately the center of gravity of the supported object. (Objects with

center of mass above the platform may be used with active control analogously to balancing a broom in one's hand.) Objects may include, but are not limited to devices that require external power or devices that possess their own power and are operated via wireless signals. Supported objects that may be moved comprise any camera system including but not limited to camera systems with vertical spars such as those found in Austrian Patent 150,740 with or without the combination of two-axis active stabilizers as found in U.S. Patent 2,446,096, U.S. Patent 1,634,950, U.S. patent 2,523,267 (also comprises a three axis active embodiment), U.S. Patent 1,731,776 and Great Britain Patent 516,185 all of which provide active control in the two horizontal axes in order to maintain a camera support in a vertical position. The camera system of U.S. Patent 4,625,938 which comprises a vertical spar and a means for stabilizing the spar may be supported and moved via using embodiments of the invention rather than the support technique described in the '938 Patent. Helicopter or airplane mounted cameras such as 3,638,502 may be supported and moved in embodiments of the invention utilizing passive or active stabilization whether mounted at the center of gravity or not, which is

not possible using prior art techniques since embodiments of the present invention move objects in a more stable manner.

- [0024] The term stabilization as used herein comprises any mechanism for stabilizing an object about its axes. Passive stabilization may utilize struts or damping agents that limit the pendulum motion of a suspended object. Active stabilization utilizes sensors to provide feedback to a powered axis in order to controllably stabilize an axis in a given direction, velocity, acceleration, jerk or any other derivative of space over time.
- [0025] The term line as used herein refers to a continuous and unbroken length of line that can bend and be directed through any number of passive or powered or active line support elements or any other redirection mechanism. In one embodiment of the invention line breakage causes components associated with the line to become non-functional. To avoid this issue and thereby enhance system safety, the invention contemplates the use of a limiting mechanism to keep a supported object from making contact with the area of coverage. By supporting an object on a plurality of sides with a single line, there is a built in safety characteristic not found in the prior art whereby

one line may break without causing the supported object to contact the ground below. For example, if an object is supported on four sides, with one line reeved and coupled with two of the four opposing sides, and the other line (or line side in a one line embodiment) coupled with the other two of the four opposing sides whether ninety degrees apart or not with respect to the first line, then breakage of one line (or line side wherein the other line side is coupled for example on a winch whereby half of the line breaking does not release tension in the other half), does not allow for the platform to contact the ground below. In buoyant embodiments, a break in a line does not allow the platform to escape vertically to the sea surface or in a balloon embodiment to float away or damage a stadium ceiling for example. Zero-G environments with magnetic direction force elements would not escape into space for example if one line were to break.

- [0026] A drum winch is a device that operates on a last-in-first-out basis for storing line and controlling the length of deployed line that is coupled with the drum. Thus a drum winch operates in much the same way that a reel (e.g., a fishing reel) does. A push-pull wheel works in a completely different way from a drum winch and is

functionally a motorized pulley that operates on a first-in-first-out basis for relocating line without storing the line for later extension. The push-pull wheel does not change the amount of line deployed, but rather relocates line from the intake side to the outlet side of the device.

- [0027] The word motor as used herein refers to a motor which may comprise a drive pulley or drum winch or any other device that can relocate line or cable. This definition is provided for purposes of ease of illustration since a motor must drive some type of device to relocate line. In addition, in certain embodiments motors may be substituted with hydraulics, electric actuators or any other method of moving line and keeping within the scope and spirit of the invention.
- [0028] Some examples of the type of line embodiments of the invention that may be utilized include synthetic rope fibers such as but not limited to HMDPE (High Molecular Density Polyethylene) fibers such as Spectra, or improved fibers such as Vectran. Line of this length, strength and weight allows the platform to be deployed over large distances. Synthetic line is 90 percent as strong as metal cable while having 10 percent of the weight.
- [0029] Embodiments of the invention may be nested in order to

support and move multiple independent or dependent objects. Dependent objects may for example comprise a pole coupled with a plurality of reevings that may keep a pole aligned vertically or may be moved independently in order to angle the pole with respect to any axis. Rigid couplings with a fixed distance between a plurality of reevings coupled to the pole may be utilized or non-rigid dependent couplings may also be utilized including telescoping poles or elastic bands for example. A plurality of lines irrespective of reeving may be coupled with a pole in order to provide a platform for a microphone for example.

- [0030] Independent objects may moved independent of one another and may also for example be controlled by one computer in order to avoid collisions between the independent objects. Collision sensors may be coupled with any element in the system in order to provide for collision avoidance with another object suspended and moved by another reeving instance, or with a stationary or moving object not associated with an embodiment of an invention as long as the position of the object is known to the system. Acoustic, optical or radar sensors, i.e., collision sensors, may be coupled anywhere within the system in order to reposition the supported object and/or line(s) in order

to avoid a collision with a soccer ball, baseball, football or other sporting implement such as a javelin, hammer, shot put, or any other object that is capable of being detected. In pre-planned movements involving simulation, collision detection may be utilized in order to avoid a collision with an object that is sensed during actual movement of the physical embodiment followed by either exiting the pre-planned flight path or returning to the pre-planned flight path after avoidance.

BRIEF DESCRIPTION OF DRAWINGS

- [0031] Figure 1 is a perspective view of the overall system.
- [0032] Figure 1A is a perspective view of the overall system without line travel between supports.
- [0033] Figure 1B is a perspective view of the overall system without line travel between supports showing a buoyant aerial or buoyant aquatic embodiment.
- [0034] Figure 1C is a perspective view of a nested embodiment showing two independent systems.
- [0035] Figure 1D is a perspective view of a nested embodiment with an articulated arm or boom platform.
- [0036] Figure 1E is a perspective view of a nested embodiment employing a pair of non-buoyant embodiments and a

buoyant embodiment.

- [0037] Figure 1F is a perspective view of a recursively nested embodiment showing a rectangular embodiment supporting a triangular independent embodiment.
- [0038] Figure 1G is a perspective view of a nested dependent embodiment with a rod coupling each platform.
- [0039] Figure 1H is a perspective view of a nested dependent embodiment supporting an articulated arm or boom platform.
- [0040] Figure 1I is a perspective view of a nested dependent embodiment showing the ability to rotate the rod out of the vertical.
- [0041] Figure 1J is a perspective view of a nested dependent embodiment with a passively or actively stabilized platform enabling level support and movement of the platform.
- [0042] Figure 1K is a perspective view of a nested dependent embodiment showing a telescoping rod and rotational capabilities of the rod and/or platform.
- [0043] Figure 1L is a perspective view of a nested dependent embodiment showing dependence of lines in Z movement device allowing for one line total configured to support and move the platform.
- [0044] Figure 1M is a perspective view of a nested dependent

embodiment showing dependence of X line side and Y line side with respective bull wheels thereby configured to always align the rod with the vertical independent of position and with use of a minimum of one line total in the system.

- [0045] Figure 1N is a perspective view of a nested dependent embodiment comprising a Y reeving nested above an X reeving with a passively or actively stabilized platform enabling level support and movement of the platform.
- [0046] Figure 1P is a perspective view of a nested dependent embodiment comprising a nested dependent embodiment utilizing a tag line.
- [0047] Figure 2 is a perspective view of the X-axis reeving.
- [0048] Figure 3 is a perspective view of the Y-axis reeving.
- [0049] Figure 4 is a top view of a rectangular embodiment of the system.
- [0050] Figure 5 is a top view of a quadrilateral embodiment of the system where no two sides are required to have the same length.
- [0051] Figure 6 is a perspective view of an embodiment of the platform.
- [0052] Figure 7 is a perspective view of an embodiment of the

platform.

- [0053] Figure 8 is a perspective view of an embodiment of the platform utilizing a passive or active stabilized platform.
- [0054] Figure 8A is a perspective view of an embodiment of the platform utilizing a passive or active stabilized platform and counterweight.
- [0055] Figure 9 is a top view of a scalene triangular embodiment of the system where no two sides are required to have the same length.
- [0056] Figure 10 is a close up view of the reeving comprising line support elements.
- [0057] Figure 11 is a perspective view of an embodiment of the platform comprising two line support elements per side.
- [0058] Figure 12 shows reeving of a single line embodiment.
- [0059] Figure 14 shows a logical reeving diagram.
- [0060] Figure 14A shows a logical reeving diagram without line travel between supports employing two lines.
- [0061] Figure 14B shows a logical reeving diagram without line travel between supports employing one line total.
- [0062] Figure 14C shows a logical reeving diagram without line travel between supports employing two lines wherein both lines terminate without returning to the Z movement de-

vice.

- [0063] Figure 14D shows a logical reeving diagram without line travel between supports employing two lines with an alternate reeving in relation to Figure 14A.
- [0064] Figure 14E shows a logical reeving diagram without line travel between supports employing one line total with an alternate reeving in relation to Figure 14B.
- [0065] Figure 14F shows a logical reeving diagram without line travel between supports employing two lines in a triangular embodiment.
- [0066] Figures 15A–D show two line embodiments at an embodiment of the Z movement device.
- [0067] Figures 16A and 16B show one line embodiments at an embodiment of the Z movement device.
- [0068] Figure 17 shows a side view of one embodiment of the Z movement device having at least one eyelet.
- [0069] Figures 18A and 18B show an embodiment of the Z movement device employing a block and tackle for multiplication of the Z-axis traversal of the supported object.
- [0070] Figure 19A shows reeving at the Z movement device for a dependent nested embodiment employing two lines in the system, one line for the upper embodiment and one for the lower embodiment, wherein each line is for into a

half-loop thereby yielding two pairs of line ends coupled to the Z movement device.

- [0071] Figure 19B shows reeving at the Z movement device for a dependent nested embodiment employing two lines in the system, each line formed into a continuous loop.
- [0072] Figure 19C shows reeving at the Z movement device for a dependent nested embodiment employing two lines in the system, one line forming a half loop with two line ends, and the other forming a continuous loop with no line ends.
- [0073] Figure 20A shows reeving at the Z movement device for a dependent nested embodiment employing one total line in the system formed into a half loop with two line ends.
- [0074] Figure 20B shows reeving at the Z movement device for a dependent nested embodiment employing one total line in the system formed into a continuous loop having no ends.

DETAILED DESCRIPTION

- [0075] Embodiments of the invention are ideally suited for moving objects through three-dimensional space using one to more lines. Various embodiments of the invention are capable of positioning an object such as a human, animal, mining implement, logging implement, manufactured object or any other useful object. Embodiments of the inven-

tion may, for example, be used in filming movies, sporting events, or any other activity that benefits from fluid movement of a camera or other object to any position within a defined volume of space.

- [0076] In the following description, numerous specific details are set forth to provide a more thorough description of embodiments of the invention. It will be apparent, however, to one skilled in the art, that the invention may be practiced without these specific details. In other instances, well known features have not been described in detail so as not to obscure the invention. However, in each instance the claims and the full scope of any equivalents are what define the metes and bounds of the invention.
- [0077] Embodiments of the invention move an object throughout three-dimensional space by relocating line coupled with a plurality of sides of the object. In an embodiment utilizing two lines, once the displacement height of the platform is set to a minimum value for a coverage area, if one line breaks, the supported platform maintains its elevation over the ground via the unbroken line and travels to the middle of the broken line axis. The lowest the platform can descend is to the preset minimum value since opposing sides of the platform are still coupled with the re-

maining unbroken line. In buoyant embodiments such as air or sea based embodiments where the platform is generally above the supports, the highest the platform can ascend is to the preset maximum value since opposing sides of the platform are still coupled with the remaining unbroken line.

- [0078] Embodiments of the invention may comprise one line configured as an endless loop, one line configured as a half loop, two lines configured as endless loops or two lines configured as half loops. Each of these embodiments comprise two line sides designated the X line side and the Y line side, and may be termed the X line and Y line for short. In the embodiment comprising one line configured as an endless loop, approximately half of the loop is configured to effect movement of the X axis while the remaining line is configured to control the Y axis. The axes are for descriptive purposes and do not limit embodiments to orthogonal configurations. In the embodiment comprising one line configured as a half loop, approximately half of the loop is termed the X line side while the remaining line is termed the Y line side, although they may be called the X line and Y line for short. In the embodiment comprising two lines configured as endless

loops, one line is termed the X line side and the other line is termed the Y line side. In the embodiment comprising two lines configured as half loops, one line is termed the X line side and the other line is termed the Y line side, again X line side and Y line side may be termed the X line and Y line for short. Figs. 15A-D show two line embodiments while Figs. 16A, B show one line embodiments and will be explained in detail below. More lines may be utilized to support an object for extra safety but are not required and may pair up with the existing lines, or may use separate supports of unequal numbers with regards to the primary supports, and which may be separated from the primary supports by any distance or height.

[0079] Regardless of the embodiment, line is reeved in such a manner as to provide three junctions where the line can be subjected to force thereby moving an object in three dimensions that are substantially independent. Relocation of line on the X line side moves the object independent of the Y axis, while relocation of Y line side moves the object independent of the X axis. The X and Y axes are not required to orthogonally intersect. Displacing equal lengths of the line allows the Z-axis of the platform to be traversed. The Z axis is not required to project orthogonally

from the plane created by the intersection X and Y axes.

[0080] Figure 1 shows a perspective view of an embodiment of the system. The three axes are shown in the figure with the X-axis shown left to right, the Y-axis shown into the page and the Z-axis shown bottom to top of the page. The X-axis, Y-axis and Z-axis are not required to orthogonally project from the plane formed by the intersection of other two axes (meaning that each of the axes may project at angles other than 90 degrees with respect to the plane formed by the other two axes). In this configuration, support structures 110, 112, 114 and 116 surround the areas within which platform 124 is to move and separate platform 124 from the ground. Support structures may include passive or active line support elements and can comprise any structure that allows these line support elements to be distantly located to define an area of space. For instance, any structure that allows line to be redirected can serve as a support structure. A few examples of such structures include, but are not limited to buildings, trees, canyons, or any other structure with a height differential above the ground to which line support elements may be placed. Other examples comprise ground mounted supports which may have zero or nega-

tive height with respect to the volume in which the platform is to travel in, which may be used in embodiments employing buoyant platforms. Each of the support structures or support points may be at the same vertical height or may comprise different heights.

- [0081] Platform 124 provides a mobile support for any object or piece of equipment that would benefit from having the ability to move in three-dimensions. For example, platform 124 may comprise a structure which has a center of gravity well below the region where the lines pass through, about or couple with the platform. Alternatively the lines may couple with the platform at approximately the center of gravity of the supported object. Objects may include, but are not limited to devices that require external power or devices that possess their own power and are operated via wireless signals. Supported objects that may be moved comprise any camera system and include, but are not limited to, camera systems with vertical spars such as those found in Austrian Patent No. 150,740 with or without the combination of two-axis active stabilizers as found in U.S. Patent No. 2,446,096, U.S. Patent No. 1,634,950, U.S. Patent No. 2,523,267 (also comprises a three axis active embodiment), U.S. Patent No. 1,731,776

and Great Britain Patent No. 516,185 all of which provide active control in the two horizontal axes in order to maintain a camera support such as '740 in a vertical position.

The camera system of U.S. Patent No. 4,625,938 which comprises a vertical spar and a stabilizer may be supported and moved using embodiments of the invention rather than the cable support mechanism described in the '938 Patent. Helicopter or airplane mounted cameras such as 3,638,502 may be supported and moved in embodiments of the invention utilizing passive or active stabilization whether mounted at the center of gravity or not, which is not possible using prior art techniques since embodiments of the present invention move objects in a more stable manner.

- [0082] Platform 124 is supported and is moved in three dimensions by one or two lines depending upon the embodiment of the invention utilized. Each line is reeved to form a pair of "V" shapes when platform 124 is centered within the system and when viewed from above with the points of the "V" nearest platform 124. In embodiments utilizing two rope sides to support the platform, the total amount of each of the rope line sides has the same length as measured from supports 110, 112, 114 and 116 to plat-

form 124. This result is independent of the topology used, i.e., independent of the number of supports and allows for trivial Z-axis displacement. By displacing the line (either one or two lines depending upon the embodiment) from the system via Z movement device 104, platform 124 is raised. Conversely, by deploying the two line sides, platform 124 is lowered. In Figure 1, the line on the right side of X-axis motor 103 is designated 18a while the line on the left side of X-axis motor 103 (e.g., an X push-pull wheel) is designated 18b. Sides 18a and 18b are different sides of the same continuous line where the designation changes at the motor for description purposes only. The line on the right side of Y-axis motor 102 (e.g., a Y push-pull wheel) is designated 19a while the line on the left side of Y-axis motor 102 is designated 19b. Sides 19a and 19b are different sides of the same line where the designation changes at the motor. Therefore, line designations beginning with 18 signify the X line and line designations beginning with 19 signify Y line. Depending upon the embodiment of the invention implemented there is a total of one or two lines. Control of X, Y and Z-axis motors can be in the form of simple switches, potentiometers, or a computer system that takes into account

the position of the platform in order to adjust Z-axis traversal to keep platform 124 at the same Z position while traversing the X and/or Y axis, although this is not required but may be utilized for repeatability of movement sequences or any other purpose. Z-axis motor 101 and/or Z movement device 104 can be replaced by a screw or hydraulic device or any other actuator or device capable displacing line.

- [0083] In a two line embodiment employing two half loops of line, Z movement device 104 may be coupled with opposing ends of X line, side 18a and side 18b and opposing ends of Y line, side 19a and side 19b. In a two line embodiment employing two endless loops, the X line for example can be hooked into an eyelet of a winch or coupled with a non-rotating pulley that may be displaced vertically without a winch (hydraulics or screw for example) in order to displace X line in the system in order to adjust the vertical placement of platform 124. This means that not only is there a two line embodiment comprising two half loops each with a pair of ends, but there is a two line embodiment where each line is in an endless loop with no ends. Although both lines may be formed into half loops, one or the other line may be formed into a half loop while the

other line is formed into an endless loop. For example the X line could be an endless loop coupled with Z movement device 104 with a winch eyelet while the Y line could be a half loop with both ends coupled with a different portion of the winch. These embodiments are shown in Figs.

15A-D.

- [0084] Regardless of the number of line ends (zero or two) for each line in the two line embodiment, line support element 120 is coupled with Y line side 19a. These line support elements may be passive (e.g., pulleys or sheaves), however if control software is utilized to coordinate movement may also be active (e.g., motorized push-pull wheels or pulleys). Active components may be utilized to further stabilize platform 124 during movement or acceleration. Line support element 122 is coupled with Y line side 19b. Line support element 121 is coupled with X line side 18a and line support element 123 is coupled with X line side 18b. By rotating X-axis motor 103 clockwise in the figure, thereby decreasing the amount of line on X line side 18a, which increases the amount of line on X movement side 18b, the platform moves in the positive X direction, to the right in the figure. By rotating Y-axis motor 102 clockwise in the figure, thereby decreasing the

amount of line on Y line side 19a, which increases the amount of line on Y movement side 19b, the platform moves in the positive Y direction, into the figure. Line support elements 120, 121, 122 and 123 may freely rotate or may comprise active components to further aid in stabilizing platform 124.

[0085] Figure 10 shows an embodiment of the reeving in support structure 110 and line support assembly 105 detailed with each line redirected through therein. As this is a logical pattern for purposes of illustration, one skilled in the art will recognize that the various line support elements may be rearranged and realigned to minimize the space taken up by line support assembly 105 and line may be redirected to alternate supports in other embodiments of the invention. Figure 10 shows one possible embodiment with screw 1000 driving Z movement device 104 upward and downward in order to displace line into and out of the system. Any type of device capable of displacing line may be used in place of Z movement device 104.

[0086] Generator and electronic drive units 100 may be utilized to power Z-axis motor 101 and or Z movement device 104, X-axis motor 103 and Y-axis motor 102. Any other source of power may be used for the motors. Z-axis mo-

tor 101 may drive Z movement device 104 configured as a drum winch with separate areas for holding line sides. Z movement device 104 displaces line into and out of the system. For ease of illustration, other possible Z movement device 104 embodiments are not shown, such as but not limited to electronic actuator components. X-axis motor 103 and Y-axis motor 102 drive bull wheels, push-pull wheels or powered pulleys, and are also not shown for ease of illustration. Push-pull wheels move line in a first-in-first-out manner without engaging a line end and act to transfer line without storing line while drum winches move line in a last-in-first-out manner and store line that is later reeled back out. Push-pull wheels (e.g., drive pulleys) and drum winches that minimize line wear and provide anti-derailing features may be employed to drive the line in the system.

- [0087] An embodiment of the invention can run fiber optics cables or power cables along X line side 18b or Y line side 19a from support structure 110 to platform 124. Support structures 112, 114 and 116 can alternatively supply power to the platform via identical means. Platform 124 may alternatively house devices with collocated power supplies negating the need for external power cables. De-

vices attached to platform 124 may include wireless or other remote controlled devices and may comprise their own active or passive stabilization. Lines comprising electrical transmission characteristics may loop many times through a line support element 120 in order to inductively transfer power to platform 124 with the number of coils about line support element 120 and the number of coils on platform 124 effectively forming a transformer with the ratio of coils determining the reduction or increase of voltage.

- [0088] Figure 1A is a perspective view of the overall system without line travel between supports. By redirecting line that could optionally travel between supports such as 112 and 110 through redirection sheaves coupled near platform 124, it is possible for embodiments of the invention to eliminate the need for line to travel between supports. Redirection sheave assemblies 117, 118 and 119 are shown spaced apart from platform 124 for ease of viewing. It is feasible to modify the reeving using any number of redirects or other mechanisms and stay within the scope and spirit of the invention. For example, outermost sheave at redirection sheave assembly 119 could be eliminated and moved to the opposing side of platform 124 if

line 19b was redirected via platform 116 to platform 114 instead of via platform 112 to 114. This would give rise to sheave assemblies comprising 3, 2, 2, and 1 redirection sheaves for redirection sheave assemblies 119, 118, 117 and a new sheave assembly near sheave 122 (not shown for brevity). Figures 14D and 14E describe other embodiments with fewer sheaves in the sheave assemblies. Figure 14D shows travel of line between diagonally opposed supports via sheaves 143 and 144 that allow travel of the line between the support in the lower left of the figure housing Z movement device 104 and the upper right support in the figure. This would equate in Figure 1 to reeving line directly between supports 110 and 114 above the platform, namely lines 18a and 19b. This is not shown for brevity.

[0089] Figure 1B illustrates a buoyant embodiment with counterweight 804 realized as a balloon. Rod 800 is shown elongated and not to scale for ease of illustration. A buoyant embodiment may be converted to a non-buoyant embodiment by allowing the gas from the balloon to escape (or air to be replaced by water in an aquatic embodiment). Conversion from a non-buoyant embodiment to a buoyant embodiment could occur by filling a balloon with gas for

example. An embodiment may be converted from an aerial embodiment to an aquatic embodiment by lowering the platform into the water and then converted, for example, into a buoyant embodiment by filling counterweight 804 with air and lowering any associated supports. Conversion between aerial and aquatic and buoyant and non-buoyant embodiments may be performed at any time or simultaneously. The description of the movement of line through the system as per Figure 1 is complemented with the additional movement of line through the redirection sheave assemblies.

- [0090] Figure 2 shows an embodiment of the X-axis reeving. X movement in the positive X direction, to the right in the figure, is accomplished by rotating X-axis motor 103 clockwise in the diagram. As X-axis motor 103 rotates clockwise, line 18a moves down support structure 110 from line support assembly 105 from support structure 112 and hence out of line support element 121. Both lines shown between support structures 110 and 112 are designated 18a, and they are indeed the same line, although the top line only moves during Z-axis traversal. As the line leaves line support element 121 to support structure 112, it pulls platform 124 to the right in the positive X-

axis direction. At the same time, X line side 18b flows upward from X-axis motor 103 to line support assembly 105 to support structure 116 and into line support element 123. Since the length of X line side 18a on the right side of platform 124 is decreasing in length while the length of X line side 18b on the left side of platform 124 is increasing, the platform moves to the right, in the positive X-axis direction. The converse applies for motion in the negative X-axis direction by rotation X-axis motor 103 in the other direction. Modifications to the reeving in the system may be made such as switching the origination points of line side 18b heading into line support element 123 from support 110 to 116 and visa versa. Other modifications can be made to the reeving while keeping with the spirit of the invention. This includes eliminating line travel between supports by terminating the line on the support 114, and by running line from supports 112 and 116 through redirecting pulleys coupled with platform 124. The total amount of line 18 in the system does not change in order to move platform 124 in the X-axis, it is merely transferred from one side of platform 124 to the other side of platform 124.

[0091] Rotating Z-axis motor 101 in one direction rotates screw

device 1000 which raises Z movement device 104, which increases the length of deployed line in X line sides 18a and 18b. This lowers the platform in the Z-axis direction. As Z movement device 104 rises, X line side 18a moves upward into line support assembly 105 to support structure 112, to support structure 114 and into line support element 121. At the same time, X line side 18b, also attached to Z movement device 104 moves upward into line support assembly 105 and into line support element 123. Since both sides of platform 124 have increased line length, the platform lowers. Conversely, rotating Z-axis motor 101 in the other direction raises platform 124.

[0092] Note that Z movement device 104 can comprise a sequence of pulleys for multiplying the Z-axis traversal (see Figure 18), and may also utilize a block or other device for disabling travel in case of line breakage in or around Z movement device 104. By placing a backup means of limiting the upward travel of Z movement device 104 the platform can be configured to never reach the ground beneath it even if a failure beneath Z movement device were to occur.

[0093] Figure 3 shows an embodiment of the Y-axis reeving. Y movement in the positive Y direction, into the figure, is

accomplished by rotating Y-axis motor 102 clockwise in the diagram. As Y-axis motor 102 rotates clockwise, line 19a moves down support structure 110 from line support assembly 105 and out of line support element 120. As the line leaves line support element 120 to support structure 110, it pulls platform 124 into the figure, in the positive Y-axis direction. At the same time, Y line side 19b flows upward from Y-axis motor 102 to line support assembly 105 to support structure 116 and into line support element 122. Since the length of Y line side 19a on the top side of platform 124 is decreasing in length while the length of Y line side 19b on the bottom side of platform 124 is increasing, the platform moves into the figure, in the positive Y-axis direction. Note that the Y line sides 19a and 19b between support structures 110 and 112 only move during Z-axis traversal. This is also true of line 19b between support structures 112 and 114. The total amount of line 19 in the system does not change in order to move platform 124 in the Y-axis, it is merely transferred from one side of platform 124 to the other side of platform 124.

- [0094] Rotating Z-axis motor 101 in one direction increases the length of deployed line in Y line sides 19a and 19b. This

lowers the platform in the Z-axis direction. As Z movement device 104 (shown in Figure 3 as a drum winch) rotates, Y line side 19a and 19b moves upward into line support assembly 105. Both line sides travel to support structure 112. Y movement side 19a travels into line support element 120, and 19b travels to support structure 114 and into line support element 122. Since both sides of platform 124 have increased line length, the platform lowers. Conversely, activating Z-movement device to displace Y line 19 (both sides) in the opposite direction causes the platform to rise. One skilled in the art will recognize that line 19b may be reeved to bypass support 112 and may travel directly from support 110 to support 114 or may be reeved through support 116 instead of 112 before traveling to support 114.

- [0095] Referring to Figure 1, since all of the line supporting platform 124 from line sides 18a and 18b travels directly next to line sides 19a and 19b from each support, e.g., since each support has a length of line 18 and 19 traveling to platform 124, the total amount of line deployed from the supports of line 18 is equal to the total amount of line deployed from the supports of line 19 to the platform no matter where platform 124 is. This allows for trivial con-

trol of Z-axis displacement since all of the line may be moved in the same amount to effect Z-axis displacement. This is not possible with one cable per support pulley per motor per winch systems since all of the line lengths change unequally depending on where the supported object is.

- [0096] A one line embodiment of the invention is formed by connecting one end of the X line to one end of the Y line, thereby yielding one line with two ends total. Another embodiment of the invention is created by connecting the remaining two ends of line, i.e., the other end of X line to the other remaining end of Y line in order to form a single endless loop of line. See Figs. 16A and 16B. Z-movement device 104 then may comprise two non-rotating line support elements that are moved to or away from line support assembly 105 in order to control the Z-axis displacement of the system. The one line embodiment is therefore formed from the two lines by connecting the two lines together to form a single strand of line and either closing the loop or leaving two ends un-joined (zero or two line ends total). Following the single length of line through the system shows that indeed three-dimensions of travel can be asserted on an object with one single continuous piece

of line with zero or two total ends. The single line may have four knots tied somewhere along the stretch from Z movement device 104 to line support element 105 that limit the travel of line in case of a break, any other technique of limiting the line travel for a single break may also be used including brake systems in at least one support structure or on line support elements coupled with platform 124.

[0097] Figure 12 shows an embodiment of Z movement device 104 for example configured to use a hydraulic device with two non-rotating line support elements connected to the top of Z movement device 104. As Z movement device 104 extends or contracts vertically in the Figure, more or less line is deployed or displaced that supports platform 124. As all line in the embodiment is one piece of continuous line that has no ends, it is designated line 20, however, line 20 comprises X line side 18 and Y line side 19 where the designation changes at the Z movement device with X line side 18 designated as line 20 between Z movement device 104 that is coupled with X-axis motor 103 and with Y line side 19 designated as line 20 between Z movement device 104 that is coupled with Y-axis motor 102. Z movement motor 101 in this embodiment com-

prises a hydraulic system. Another embodiment of Z movement device 104 may be a screw or electronic actuator or any other device that could possibly move the two line support elements associated with the device through a distance. One skilled in the art would recognize that reeving in several more line support elements to form a block and tackle between Z movement device 104 and line support element 105 in order to make a Z multiplication factor is readily possible as per Figs. 18A and 18B. Another embodiment of the invention whereby only one line support element is used on Z movement device 104 exists where two of the line ends of line 20 are coupled with Z movement device 104 and where the single line support element is the designated dividing point for X line side 18 and Y line side 19 as per Figure 16A. Coupling two line ends to Z movement device along with a pulley allows for a single half loop of line 20 with two line ends to move platform 124 in three-dimensional space. Coupling the remaining two ends to form one endless loop of rope is shown in Figure 16B. The eyelets of Z movement device 104 shown in Figure 17 may allow free travel of line 20 through each eyelet until Z movement device 104 is rotated until travel through the eyelets is not possible. This

allows the X and Y axis push-pull wheels to have immobile junctions in which to pull against so that line does not freely travel through the entire system. As the hydraulic device of Z movement device 104 may be replaced by a single winch with eyelets or separate areas for X line side 18 and Y line side 19 of line 20, it should be clear to one skilled in the art that a hydraulic device is not required to practice the invention and that any mechanism which displace Z movement device 104 may be substituted.

- [0098] As shown in Figure 12, line 20 is a single piece of line comprising X line side 18 and Y line side 19 as per Figure 1, which may be termed X line and Y line for short since these sides of line 20 are utilized to move through the X axis and Y axis respectively even though they are simply different sides of the same line 20. Line 20, i.e., Y line side 19 (side 19b in Figure 1) extends from the far left side of Z movement device 104 up to line support element 105 to support structure 112 to support structure 114 to line support element 122 to support structure 116 to line support element 105 down to Y-axis motor 102 back up to line support element 105 (now side 19a in Figure 1) to line support element 120 to support structure 112 to line support assembly 105 right line support element on Z

movement device 104 back up to line support assembly 105 (now line 18, side 18b in Figure 1) to line support element 123 to support structure 116 to line support assembly 105 to X-axis motor 103 back up to line support assembly 105 (now side 18a in Figure 1) to support structure 112 to line support element 121 to support structure 114 to support structure 112 to line support assembly 105 to the left line support element on Z movement device 104, thereby completing the single loop of line reeved through this embodiment of the invention. For the endless loop embodiment, one or both of the two line support elements shown on top of Z movement device 104 may be non-rotating so that X-axis motor 103 and Y-axis motor 102 have a fixed point in which to pull against, otherwise platform 124 would not move as all line support elements in the system would free spin. The endless loop of line could be cut at one of the non-rotating line support elements with both resulting line ends attached to Z movement device 104 yielding a single piece of line embodiment that is formed into a half loop of a single line instead of an endless loop of line of a single line, this also provides points at which to immobilize line so that the single line with two ends embodiment does

not freely spin. See Figure 16A. Although line 20 is one continuous piece of line it possesses X line side 18 and Y line side 19 upon which forces may be applied in order to relocate line onto each side of platform 124 in order to move it.

[0099] Figure 4 shows a top view of an embodiment of the system in a rectangular configuration. Although line support assembly 105 has been designated in the figure, each of the support structures may have line support assemblies of lesser complexity. Support structure 112 for example may have four line support elements while support structures 114 and 116 may have two line support elements. Each of the line support elements can comprise any device that can guide the line into the line support element securely. Line support element assembly 105 for example may have eight line support elements, four for Z-axis traversal, two for X-axis movement and two for Y-axis movement or any other number of line support elements that allow X and Y line to move. See Figure 10 for an example close-up of support structure 110 and line support assembly 105. The exact layout of the support elements used can be varied for space considerations or any other design requirement while keeping with the spirit of the

invention. Any element capable of redirecting line may be used in place of a line support element.

- [0100] Figure 5 shows a non-rectangular embodiment of the system. In this embodiment, if lines were drawn between the four support structures 110 to 112, 112 to 114, 114 to 116 and 116 to 110, a convex quadrilateral would result. Concave quadrilateral embodiments may be configured by moving support structure 114 across a line drawn between support structure 112 and 116. Since the X-axis and Y-axis lines are equal length for each stretch between support structures, it follows that the support structures may be moved while maintaining full functionality of the system. This means that the support structures may be mobilized and physically moved before or during operation of the system.
- [0101] Figure 9 shows a triangular shape embodiment that is constructed with three support structures instead of four for example by eliminating support structure 112 and the four line support elements in it. The length between support structure 110 and 116 is the shortest, the length between support structures 110 and 114 is longer and the length between support structures 114 and 116 is the longest stretch. Since the three sides of the triangle are

not required to be of the same length a scalene triangle is formed although isosceles and equilateral triangular embodiments may also be constructed by placing the support structures at the required positions. Eliminating support structure 112 and the four line support elements in it accomplished by coupling line support assembly 105 lines to support structure 114 directly. Since the total lengths of the X and Y line are the same within the system, the same Z movement device may be utilized to raise and lower the platform. That area of coverage is a three sided triangle where no two sides are required to be of the same length.

[0102] Figure 14 shows a logical diagram of a two line embodiment with slightly different reeving in that there is no open side without line. In addition, this embodiment shows that X axis motor 103 and Y axis motor 102 may be repositioned within the reeving. This figure also shows that modifications to the reeving are possible while keeping within the scope and spirit of the invention. This embodiment also shows Z movement device 104 as a winch attached to the two sets of line ends. One line is shown in dashed lines for clarity. Movement of X axis motor 103 comprising a push-pull wheel for example transfers line

from the left side of the diagram to the right side of the diagram and visa versa. The transfer of line does not alter the amount of line in the system. Line support elements 121 and 123 allow Y line to pass through as X line is transferred out of line support element 120 and into line support element 122 for example. This holds for independent movement of Y line as well via Y axis motor 102 comprising a push-pull wheel for example. Since the total amount of X line and Y line remains the same as measured from the supports to the supported object, X movement is independent from Y movement, while Z movement may be performed by a single mechanism. Three and four support arrangements also comprise equal lengths of line supporting an object where no two sides are required to be equal length. Activation of Z movement device 104 displaces equal amounts of line via one side of each line support element 120, 121, 122 and 123 and raises or lowers the platform.

- [0103] Figure 14A shows a logical reeving diagram without line travel between supports employing two lines. Figure 1 shows one open side (the nearest side facing the reader) with no direct line travel between supports 114 and 116, but with direct line travel between supports 110 and 116,

between 110 and 112, and between 112 and 114. One skilled in the art will recognize that the basic mechanism of transferring line from one side of the embodiment to the other is independent of the reeving bypassing or allowing for direct travel between supports. Therefore, any combination of direct and indirect travel of line in the system while ensuring that the total amount of X line and Y line as measured from the supports to the platform is in keeping with the spirit of the invention. Redirection sheaves 140, 141, 142, 143, 144, 145, 146 and 147 redirect line that would have traveled between supports to locations near the supported platform. This embodiment shows X line 18 as solid and Y line 19 as dashed for ease of viewing. Movement of the suspended platform is as in the description of Figure 14 with the additional redirection of an equal length of X line 18 and Y line 19 as totaled from the supports to the supported platform.

- [0104] Figure 14B shows a logical reeving diagram without line travel between supports employing one line total. This embodiment shows that one line with proper reeving can support and move an object from four support points in three dimensions by applying force along three locations of line 20.

[0105] Figure 14C shows a logical reeving diagram without line travel between supports employing two lines wherein both lines terminate without returning to the Z movement device. By employing a simplified reeving as shown in Figure 14C, less line is used in the system. Since only half of the system is elevated or pulled down by Z movement device 104, X and Y axes motors 103 and 102 may be adjusted in order to keep the X and Y position of a supported object constant while adjusting the Z axis position of the supported object whether buoyant or non-buoyant, aerial or aquatic. The lines are shown terminated as "X" marks in the upper right hand corner of Figure 14C. The termination points may be tied to suitable weights or anchor points or any fixed or moveable object that can counteract the force applied to lines 18 and 19.

[0106] Figure 14D shows a logical reeving diagram without line travel between supports employing two lines with an alternate reeving in relation to Figure 14A. This embodiment is a shorter line length embodiment that is shown in Figure 14A in that Y line 19 does not travel completely around the upper left portion of the figure but rather travels directly near the supported object back to Z movement device 104. Likewise, X line 18 bypasses the support in

the lower right portion of the figure and travels directly from redirection sheave 144 to Z movement device 104. This embodiment provides substantially independent X, Y and Z control with minimal extra line compared to the embodiment depicted in Figure 14C. In Figure 1A, this would equate to eliminating the topmost sheave in redirection sheave assembly 119, placing the eliminated sheave on the opposing side of the platform and bypassing support 112 in the reeving. The topmost sheave in redirection assembly 117 could therefore be eliminated along with the third sheave down in redirection sheave assembly 119 since the remaining redirection sheave in redirection assembly 117 could be routed directly to support 110 without traveling to support 112.

- [0107] Figure 14E shows a logical reeving diagram without line travel between supports employing one line total with an alternate reeving in relation to Figure 14B. This embodiment is a one line embodiment of the embodiment depicted in Figure 14D.
- [0108] Figure 14F shows a logical reeving diagram without line travel between supports employing two lines in a triangular embodiment. Operation of the triangular embodiment is identical as the operation of any rectangular embodiment.

ment in terms of control inputs to X-axis motor 103, Y-axis motor 102 or Z movement device 104. The difference in triangular and rectangular embodiments is the number of support points and the volume covered. In addition, since there is one less support, there are two less redirection sheaves required to take the two lines or two line sides of one line to the non-existent support.

- [0109] Figs. 15A–D show two line embodiment logical reevings that may occur at the bottom left portion of Figure 14 while Figs. 16A–B show one line embodiment logical reevings.
- [0110] Figure 15A shows an embodiment of the invention utilizing two lines 18 and 19 wherein each line's ends are attached to Z movement device 104. Figure 15B shows an embodiment wherein line 18 has its ends attached to Z movement device 104 while line 19 is configured as a loop through an eyelet. The side view of Z movement device 104 is shown in Figure 17 with eyelet 1700 shown on the left, with axle 1701 shown in the center. Figure 15C shows line 18 configured as an endless loop with line 19 having its ends attached to Z movement device 104. Figure 15D shows an embodiment wherein both lines 18 and 19 are configured as endless loops that loop through eye-

let 1700 as shown in Figure 17. Figure 15D may be configured to limit travel of line 18 and/or 19 through the eyelets to provide the X and Y motors with fixed locations to pull against. If there are no fixed locations in the system at all, the line in the system will freely spin. However, once a rotation of Z movement device 104 has occurred, wherein for example Z movement device is configured as a winch, then of course, lines 18 and 19 would not freely spin through the eyelets once line was wound about the winch.

- [0111] Figure 16A shows an embodiment of the invention near the Z movement device employing only one line configured as a half loop wherein two ends of line 20 are attached to Z movement device and line 20 passes through eyelet 1700. Figure 16B shows an embodiment of the invention employing line 20 as an endless loop throughout the system with line 20 passing through a pair of eyelets 1700 on Z movement device 104. Figure 16B may be configured to limit travel of line 20 through the eyelets to provide the X and Y motors with fixed locations to pull against. If there are no fixed locations in the system at all, the line in the system will freely spin. However, once a rotation of Z movement device 104 has occurred, wherein

for example Z movement device is configured as a winch, then of course, line 20 would not freely spin through the eyelets once line was wound about the winch.

- [0112] Although the embodiments shown in Figures. 15A-D and 16A-B are easily transformed near Z movement device 104, other arrangements utilizing one line or two lines in the system may be accomplished by separating the junctions where force is applied to line. Additional insertion of two wheel winches that reel in one line and reel out a separate line at the same rate can be inserted anywhere in the system in order to create embodiments employing as many lines as is possible, however, these embodiments can be replaced by embodiments having fewer lines until only one or two lines are utilized in the system. Regardless of the number of lines, if the length of the two lines or two sides of one line between the supports and the platform is the same, then Z movement is accomplished with one Z movement device and X and Y movement is substantially independent. By utilizing an embodiment where X, Y and Z forces are applied in a centralized location, maintenance is easily performed however embodiments of the invention relocating various components are clearly within the scope of the invention.

[0113] Figure 18A shows an embodiment utilizing Z axis multiplication. Embodiments of the invention may utilize a block and tackle arrangement in the Z axis so that a limited amount of travel of Z movement device 104 may displace a multiplied amount of line into the system. The multiplication of Z axis travel may also be utilized for coverage areas that are deeper than the distance from the Z movement device to the supports, e.g., for an embodiment with 30 meter supports, a 10 factor block and tackle can be utilized yielding 300 meters as the maximum distance displaced in the Z-axis. For example, in Figure 18A, with Z movement device 104 in the lowest position as shown, approximately three times the amount of line exists as opposed to Figure 18B when Z movement device is raised, yielding in this example a multiplication factor of three. Rod 1800 may be a hydraulically actuated rod in an embodiment of the invention, while Z movement motor 101 may drive a hydraulic pump. There is no requirement that Z movement motor must actually be an electric motor, as any device capable of displacing line may be used in place of an electric motor with the understanding that motor as defined herein defines any mechanism capable of displacing line.

[0114] Figure 6 shows close up perspective of platform 124. This embodiment of the platform is suspended beneath the crossbar 601. Each of the line support elements 120, 121, 122 and 123 may be hinged with universal joints. Line support element 120 may be hinged to crossbar 601 by universal joint 620. Single axis rotatable axles may be used in place of universal joint 620. Platform 124 is suspended from crossbar 601 by platform post 600. Any useful device or object may be mounted on the platform. For example a winch with a harness for raising and lowering an actor may be coupled with the platform. For aquatic embodiments, the platform may be on the top of the diagram with a counterweight below. The platform itself may comprise active or passive stabilization in between crossbar 601 and post 600. Post 600 may or may not extend above crossbar 601, and any extension above the crossbar may or may not be balanced with regards to the center of gravity of the total resulting mass attached to post 600. In other words, the center of gravity may lie above, below or at the center of gravity of the resulting object supported. When the center of gravity lies above the support point care must be taken to place the center of gravity close enough to the support point so that the

platform does not tip over, which can also be accomplished via active control if desired. In general, placement at the center of gravity or where the support point is above the center of gravity allows passive or even pure free wheeling isolation to be employed. Crossbar 601 may be substituted with any structure capable of coupling with lines including but not limited to a circular or rectangular object.

- [0115] Figure 7 shows a close up perspective of platform 700, another embodiment of a platform. This platform is supported by line support elements 120, 121, 122 and 123 via universal joints. Platform 700 contains an isolator, for example at least a one axis free spinning gimbal mount 702 with inner platform 701 which may support any useful device and may be further comprise powered axes which may be moved by direct or wireless command. The embodiment may comprise an isolator with one or more axes of platform 701 are isolated and free rotating, or passively stabilized with dampers or actively stabilized in terms of pitch, roll and pan axis rotation. The active stabilization may be position, velocity, acceleration, jerk or any other order to distance per time derivative. Platforms may be rotatable from the inside as shown or via the out-

side of platform 700 (which would comprise a circular outer shape not shown for brevity. Figure 11 shows a variation of Figure 7 with two line support elements per side. In this embodiment, each side of platform 700 couples with an opposing line via two pulleys per side. Embodiments may employ line support elements of any number or any size on the platform.

- [0116] Figure 8 shows a close up perspective of platform 124 supported by a passive or active stabilization system 803, which may exist at crossbar 601 (not shown for brevity) or at platform 124 as shown, supported by rod 800 which may comprise a counterweight (shown in Figure 8A) at the top of rod 800 with rod 800 mounted on crossbar 601 slightly above the center of gravity of the combination of platform 124, rod 800 and counterweight 804. Crossbar 601 may be hinged with a universal joint or may comprise a gimbal as shown in Figure 7. Many more platform embodiments are possible and the platforms shown in Figs. 6, 7, 8 and 11 are merely a small set of examples of the myriad of configurations possible. Any camera assembly including but not limited to those with vertical or horizontal orientations and with or without active or passive stabilization may also be supported and moved with embodi-

ments of the invention. Since the X and Y line (in one or two line embodiments) supports platform 124 from upward angles on each of the platforms sides, there is no need for a tag line or gimbal assembly to provide further stabilization although embodiments of the invention may utilize such a device. In fact, the line support elements on platform 124 act as tag lines for moving platform 124 through three dimensional space.

[0117] Figure1 shows an embodiment of the invention that uses single line support elements at all line direction points. Other embodiments may use multiple line support element arrangements virtually anywhere where a single line support element is used in order to change direction of a line and further prevent derailing. Line support elements with groove shapes and rounded edges that minimize the lateral friction on lines passing through the line support elements may be utilized in order to minimize the amount of wasted power in the system. Embodiments of the invention may use any type of line support element that works with the line specified for the system. Any linear connection device may be utilized in place of line, such as but not limited to cable. A dynamometer may be inserted in-line between Z-axis motor 101 and Z movement device

104 in order to provide tension readings.

[0118] Platform 124 can have many different apparatus attached to it to perform a variety of functions including but not limited to stabilization devices, gimbals, camera equipment, mining loaders, ship-to-ship loaders, logging devices, ski lift seats, gondolas, body sensing flight simulator suits for allowing a person to simulate flying, reduced gravity simulator suits, lifting harnesses, munitions depot bomb retrievers, digital video equipment for security checks in railroad yards or nuclear facilities, robotic agricultural harvest pickers for quickly picking and storing grapes or other produce or any other device that benefits from repeatable placement and motion in three dimensional space. In another embodiment, platform 124 comprises a witness camera mounted pointing down from the platform, providing a picture from the viewpoint of the platform. Camera systems previously described may be mounted at above or at approximately the center of gravity of each device with active, passive or a combination of active and passive stabilization in any number of axes, some of which may be multiply actively or passively stabilized. Platform 124 may comprise line support elements that may or may not be located on opposing sides of the

platform as long as a line supporting platform 124 travels to supports that oppose each other in order to prevent ground collision in the case of a break on another line side.

- [0119] In addition to moving platform 124 as per an operator input, embodiments of the invention contemplate the use of a virtual system simulation to pre-plan platform travel paths and thereby determine a preferred camera angle or platform position. The system stores the path information for subsequent use in a physical environment. Once the physical structure implementing one or more aspects of the invention is erected the path data provides a basis for movement of the platform or any object coupled with the platform (e.g., a camera). The simulation is typically performed in a computer environment scaled to match or approximate a physical location such as a football stadium or movie set. Thus, users of the system described herein (or any other rigging system preferred for the task at hand) can attempt various configurations without having to undertake the expense of an actual system setup.
- [0120] The virtual system (e.g., rigging) is accomplished in one or more embodiments of the invention by approximating the location of key rigging components (e.g., support

structures, sheaves, etc...) and based on the present location of the platform, calculating the effects of transferring line into the system via the Z movement device or transferring line from one side of the system to the other side of the system via the X junction and Y junction. In this manner it is possible to simulate platform travel in a virtual environment before implementing the actual travel sequence in a physical environment. Adjustments or changes to the path of travel to obtain an optimal angle can be made in the virtual environment before undertaking the expense of making changes to the physical environment. Each of the virtual systems (e.g., rigs) may possess a different geometry, however, once the geometry is known, and the starting position of the platform is known, control inputs are used in order to calculate the resulting position of the platform. This technique provides a method for determining a path of travel that would avoid other virtual objects that have been measured and entered into the simulation. In addition, since the locations of the supports are known and the location of the platform is known, the location of the lines may be calculated. In this way, buildings or trees for example may be avoided by the platform and the lines and a particular travel path may be

performed over and over by computer control without human intervention or variance. Having a virtual system is advantageous in that it gives system operators the ability to simulate various system configurations and thereby determine whether it is possible to obtain specific camera angles.

- [0121] By selecting travel points to which the platform has traveled and moving these points through a graphical user interface, the control inputs can be recalculated in order to meet the desired three-dimensional path and saved for later playback on the physical embodiment. By simulating an embodiment by measuring and entering the sizes and locations of supports, and entering the sizes and locations of known obstacles or waypoints, a platform travel path may be constructed before the physical embodiment is completely assembled thereby saving time and effort in the coverage area.
- [0122] Embodiments of the invention may be nested in order to allow more than one object to be moved within a given volume of space. Any additional instance of the embodiment of the invention comprising the line or lines reeved in the spirit of the invention whether or not identically reeved as the primary reeving is reeved is termed a nested

reeving. Figure 1C shows this arrangement. Nesting may be accomplished with for example two non-buoyant embodiments in air or water, or with two buoyant embodiments whether in air or water, or with a non-buoyant embodiment above or below a buoyant embodiment whether either embodiment is in air or water or space. Figure 1D shows an articulated arm or boom 1241 supported by counterweight 1240 to offset the weight of platform 1242 possibly comprising a camera for example. It is also possible to nest more than two embodiments and with pre-planned simulation of flight paths, users of the system can move a set of objects through a set of complex paths. The ability to plan an object's path has significant benefits including collision avoidance and repeatability for example. When filming a movie for example, it is beneficial to move cameras and actors in coordinated, repeatable paths so that scenes may be filmed for a movie without separate moving objects/actors colliding. Boom 1241 may telescope outward, or to the right in the figure, with counterweight 1240 automatically moving to the left in the figure for example to keep boom 1241 at a given angle with respect to any axis.

[0123] Figure 1E shows a nested embodiment comprising two

non-buoyant embodiments with a buoyant embodiment beneath the two non-buoyant embodiments. Platform 124 may comprise a human actor, while platform 1242 at end of articulated arm or boom 1241 supported by counter-weight 1240 may be coupled with a camera and used for example to film the human actor coupled with platform 124. The articulated arm may comprise as many joints or degrees of freedom as is desired. Counterweighting the platform allows the arm to remain in a given position without oscillations, and active or passive control systems may be applied in the system to compensate for arm movement.. A camera coupled with platform 1248 which is coupled to the top of buoyant counterweight 8002 supported in the vertical direction by non-buoyant counter-weight 8001 with or without passive or active control of any axis may be also used to film the human actor or the view that the human actor would have when flying through three-dimensional space.

- [0124] Although the configuration in Figure 1E shows a buoyant embodiment on the bottom, the buoyant embodiment may be placed on top of non-buoyant embodiments as well and in any combination. Pre-planned simulation of flight paths may be utilized to control the actual flight

paths in a repeatable fashion. Although the reeving of the two non-buoyant embodiments is shown in a parallel configuration this is done for ease of illustration as the sheaves in an actual realization in the supports may be closer or more spread about than is shown. The generator and electronic drive units 100 may be used to control the non-buoyant embodiments, while a separate assembly with generator and electronic drive units 100a is used to control the buoyant embodiment. With the reeving of the buoyant embodiment switched 180 degrees so that the main sheave assembly would lie in support 110 for the buoyant embodiment, then generator and electronic drive units 100a may be eliminated and one assembly of generator and electronic drive units may be used to control all three embodiments in this example. Although the buoyant embodiment is shown in a configuration wherein the lines do not travel between supports, the non-buoyant embodiment may also employ this configuration and the buoyant embodiment may employ a configuration wherein some or all of the lines travel directly between supports. (Figure 1 shows a hybrid embodiment wherein some of the line travels between supports and some does not. This is the case since there is no direct line travel between supports

114 and 116 although line 19b traveling between supports 112 and 114 could easily be reeved directly between supports 110 and 114 or 110 to 116 to 114. This would yield an embodiment with line travel between all supports.) Embodiments may also be recursively nested with one large embodiment moving an object which actually comprises a small embodiment which may be independently controlled for example to provide fine tuning. Figure 1F is a perspective view of a recursively nested embodiment showing a rectangular embodiment supporting a triangular independent embodiment. Control of the large embodiment is separable from control of the recursively nested embodiment. One embodiment may also for example house more than one nested embodiment, either at the same level as the first recursively nested embodiment or at a deeper level, however this is not shown for brevity.

- [0125] Figure 1G is a perspective view of a nested dependent embodiment with a rod coupling each platform. By moving each Z movement device, X or Y junction, rod 800 may be positioned into any angle with respect to the vertical. By allowing the lower embodiment to lower the connection point, or upper embodiment to raise rod 800 while allow-

ing rod 800 to traverse vertically with respect to the lower embodiment (sleeve mounting the lower embodiment on rod 800), more or less lateral torque may be applied to a given scenario. Rod 800 may be configured to rotate and may be configured to telescope. Rod 800 may also comprise an articulated arm or boom. Figure 1H is a perspective view of a nested dependent embodiment supporting an articulated arm or boom platform. In this figure, rod 800 and boom 1241 may telescope or may be configured with static lengths for example.

- [0126] Figure 1I is a perspective view of a nested dependent embodiment showing the ability to rotate the rod out of the vertical. Figure 1J is a perspective view of a nested dependent embodiment with a passively or actively stabilized platform enabling level support and movement of the platform. Figure 1K is a perspective view of a nested dependent embodiment showing a telescoping rod and rotational capabilities of the rod and/or platform. As shown in the figure rod 800 has telescoped up, which is another way in which more torque could be applied to a platform. The application of more torque may be utilized in any situation, for example when an embodiment of the invention is used in mining as with a mining scoop. Platform 124 is

also shown rotated with respect to Figure 1J. Platform 124 may comprise a boom as in Figure 1H, but is not shown for brevity.

[0127] Figure 1L is a perspective view of a nested dependent embodiment showing dependence of lines in Z movement device allowing for one line total configured to support and move the platform, or for two total lines reeved in the system. This embodiment allows for simultaneous control of Z movement for both embodiments. Simultaneous movement using one Z movement device 104a keeps the distance between the two inner sheave assemblies constant as long as the support offsets for the two reeving systems comprise the same distance between reeving systems as is configured along rod 800 (see distance L shown on one support and at rod 800 in Figure 1M). Through use of one line embodiments for the upper and lower nest embodiments, two total ropes may be used as per Figures 19A, 19B and 19C (two half loops, two whole loops and one half and whole loop respectively), or with one total line in the system as per Figure 20A configured as one total half loop and Figure 20B configured as one total loop of line in the system when the upper and lower reevings are coupled together.

[0128] Figure 1M is a perspective view of a nested dependent embodiment showing dependence of X line side and Y line side (whether independent lines or part of the same single line) with respective bull wheels thereby configured to always align the rod at a constant angle with the vertical independent of position. In this configuration X movement device 103a and Y movement device 102a may be used to control the X and Y positioning of platform 124 wherein rod 800 remains vertical regardless of position without requiring active control as in prior art devices.

[0129] Figure 1N is a perspective view of a nested dependent embodiment comprising a Y reeving nested above an X reeving with a passively or actively stabilized platform enabling level support and movement of the platform. This embodiment may be thought of as a non-nested embodiment wherein half of the reeving is split apart vertically from the other half. Sheaves coupled with rod 800 may comprise braking components so that for example the upper reeving may be pulled into the figure while the lower reeving is not allowed to freely follow by halting the rotation of the lower sheaves (121, 123) coupled with rod 800, thereby angling platform 124 in the negative Y direction (out of the figure). By using powered sheaves cou-

pled with rod 800 on for example the lower portion of rod 800 namely sheaves 121 and 123, platform 124 may be rotated in the positive Y direction (into the figure) when sheave 120 has line taken out of its respective side, (i.e., the rod has been pulled into the positive y axis) by simultaneously rotating the lower X-axis sheaves which would normally freely rotate. The sheaves may loop line around them to gain more traction in some embodiments. This embodiment is shown with two separate Z movement devices, however one Z movement device may also be utilized, meaning that the entire embodiment may comprise one line. Although the embodiment shows two lines coupled with a pole comprising a platform which may comprise a video or microphone device, any other useful device may be coupled with platform 124 including but not limited to a telescoping rod, ribbonlift, telescoping boom, articulated arm or any other device. In embodiments with powered sheaves 120, 121, 122 and 123 rotation of rod 800 may occur with less line in the system than would normally be employed. Since sheaves 120, 121, 122 and 123 would require power, the sheaves could also be used to charge a battery coupled with rod 800 when moving about the coverage area, i.e., the motors coupled with

sheaves 120, 121, 122 and 123 can double as generators. By displacing line into the negative Y-axis, sheave 122 rotates while line is being removed from the positive Y-axis side of the system, thereby rotating sheave 120 and therefore sheave 120 and 122 can charge a battery coupled with rod 800 which may be utilized to power sheaves 121 and 123 or apply breaking pressure to sheaves 121 and 123.

- [0130] Figure 1P is a perspective view of a nested dependent embodiment comprising a nested dependent embodiment utilizing tag line 21. Although two lines are shown in this embodiment, there is no limit to the number of tag lines that may be utilized with any embodiment of the system. The tag line may be utilized to rotate rod 800 with respect to the vertical axis when coupled with rod 800 at an offset from a second reeving system, here shown as an X-axis reeving utilizing one rope. Any known reeving system may be utilized as one reeving and any other known reeving system may be utilized as a second reeving nested at an offset along rod 800 in order to allow for rotation of rod 800. For example, tag device 102w may be a winch in this embodiment that is utilized to pull the upper portion of rod 800 towards the support housing tag device 102w.

- [0131] Whether nested or not, embodiments of the invention may comprise radar, optical or acoustic sensors anywhere in the system, for example at platform 124 in order to provide collision avoidance with stationary or moving objects. Examples of stationary objects may include trees or buildings while examples of moving objects may comprise vehicles, sporting implements such as soccer balls, baseballs, footballs, track and field implements or any other object. By calculating the trajectory of the stationary or moving object and calculating the position of platform 124 and supporting line sides, platform 124 may be moved, thereby moving the line sides and thereby avoiding a collision with either platform 124 or line sides with an external stationary or moving object.
- [0132] Uses of the device in space with thrusters on the platform, or magnetic repulsion or attraction to provide the directional force, i.e., without need for air or water or gravity is readily achieved by adapting the platform or object being moved to comprise a magnet or compound that is attracted or repulsed in response to a magnetic field of a given direction.
- [0133] Thus, a cabling system and method for facilitating fluid three-dimensional movement of a suspended camera or

other object via a directional force has been described.

The claims, however, and the full scope of any equivalents are what define the metes and bounds of the invention.

[0134] What is claimed is: